AMENDMENTS TO THE SPECIFICATION

Please replace the paragraph beginning on page 1, line 3, with the following replacement paragraph:

BACKGROUND OF THE INVENTION

The present invention is directed to a method for negative feedback controlling electrical power delivered to an electrical load, which method comprises generically, and as known to the skilled artisan, monitoring the electrical power delivered to the load, thereby generating a monitoring signal, forming in dependency of the monitoring signal and of a rated value signal a control deviation signal and adjusting--via a controller as e.g. a proportional or proportional-integral controller--the electrical power delivered and monitored in function of the control deviation signal.

Please replace the paragraphs beginning on page 1, line 17 and ending on page 2, line 28 with the following replacement paragraphs:

SUMMARY OF THE INVENTION

It is an object of the present invention to provide such a negative feedback control method and, accordingly, such a negative feedback controlled power supply for superior accuracy of controlled power delivered to the load, with respect to a rated power value to be delivered.

Under a first aspect, the present invention departs from a method for negative feedback controlling electrical power delivered to an electrical load as mentioned above, whereat monitoring the electrical power delivered to the load results first in an analog monitoring signal, which is then analog to digital converted so as to result in a digital. monitoring signal.

Under a second aspect, the present invention departs from a method for negative feedback controlling electrical power delivered to an electrical load as mentioned above, whereat adjusting the electrical power delivered to the load and ~~monitored~~ monitoring is

performed as a function of the control deviation signal--again via a respective controller--by means of Pulse-Width Modulation (PWM).

In a method for negative feedback controlling electrical power, whereat the controlled value, namely the power delivered to the load, is digitalized as under the first aspect of the present invention, the overall accuracy of the negative feedback control significantly depends on the accuracy of the analog to digital conversion of the monitored signal. As is well known in the art of analog to digital conversion, noise of the analog input signal leads to ~~the fact that the~~ digital output signal jitters by at least one least significant bit (LSB). This problem is customarily resolved by oversampling, i.e. by establishing a sampling rate which is considerably higher than necessitated by the spectrum of the analog signal to be converted. In fact, by oversampling, a multitude of digital samples are generated in a predetermined time frame, and the respective digitalized output value is formed by averaging the digital samples. Nevertheless, oversampling is always limited by the layout of a specifically considered converter not suited to handle sampling rates above a specific maximum rate. ~~For r~~Rising the sampling rate over such limit makes it necessary to apply a differently designed A/D-converter which is often much more expensive and more critical to operate.

Please replace the paragraph beginning on page 3, line 4, with the following replacement paragraph:

This object is inventively resolved by the method mentioned above and according to the preamble of claim 1, at which the analog monitoring signal is analog to digitally converted by performing the analog to digital conversion at least twice in parallel~~,~~ ~~according to the characterizing part of claim 1~~.

Please replace the paragraph beginning on page 4, line 18, with the following replacement paragraph:

If e.g. the minimum predetermined pulse-width adjustment increment is of 30 nsec. and an actual control deviation would necessitate a pulse-width adjustment by an increment only of 10 nsec., then the calculation will reveal in preferred mode that the pulse of

predetermined length (as in a most preferred embodiment a pulse which is the predetermined minimum pulse-width adjustment increment of 30 nsec.) is to be applied in every third pulse repetition period. This leads, time-averaged as by filtering, to the same result as applying a 10 nsec. pulse in every period of PWM.

Please replace the paragraphs beginning on page 5, line 12 and ending on page 8, line 12 with the following replacement paragraphs:
According to the wording of claim 3, in a ~~most~~ preferred embodiment of the inventive method and power supply both aspects of the invention as outlined above, namely of inventive A/D-conversion and of inventive adjustment by PWM and superimposed PFM, are combined.

Although the present invention under all its aspects may be used or realized for lower power supply, in a far preferred mode of operation, it is realized for controlling the electrical power of at least 100 VA delivered to a load~~, according to the wording of claim 13~~. ~~According to the wording of claim 14, m~~Monitoring the electrical power delivered to the load may be performed by monitoring the current or voltage delivered to the load.

In spite of the fact that the above mentioned A/D-conversion, at least twice in parallel, might be applied in cases~~ too~~, where both conversions are performed at minimum required sampling rates, ~~according to the wording of claim 4,~~ additionally to the inventively performed parallel conversion, each of the A/D-conversions is performed with oversampling .

In spite of the fact that A/D-conversion in parallel could be performed in some cases at mutually different sampling rates, e.g. at sampling rates of integer ratio, ~~in a preferred embodiment and according to claim 5,~~ A/D-conversions are performed in parallel at respective equal sampling rate~~,~~.

Such an equal sampling rate may vary in time, in some applications, e.g. where the bandwidth development of an analog signal to be monitored is known in advance.

Nevertheless, in a preferred embodiment ~~according to claim 6~~, parallel A/D-conversions are performed at respective equal and constant sampling rates. In a further preferred mode the converters are operated synchronously~~, according to the wording of claim 7~~.

In a further preferred embodiment ~~according to the wording of claim 8~~, each of the at least two parallel A/D-conversions is performed with a sampling rate of at least 100 kHz, thereby resulting in an overall sampling rate of two parallel conversions of 200 kHz.

Turning back to the present invention under its second aspect or under preferred combination of both of its aspects, in a preferred embodiment ~~according to claim 9 in a most preferred embodiment~~ the pulse of predetermined length--applied by PFM--is selected to be the incremental pulse of the predetermined minimum pulse-width adjustment increment. Although this pulse needs not necessarily be of constant length, this is clearly the preferred mode~~, according to claim 10~~.

Either ~~--once again--~~ the instantaneous control deviation may be corrected by an adjustment of the PWM pulse-width by an integer multiple of predetermined minimum pulse-width adjustment increments, or the instantaneous control deviation may only be accurately corrected by adjusting pulse-width modulation as was just explained and by additionally providing for applying pulses, preferably of the predetermined minimum pulse-width adjustment increments, by pulse frequency modulation, i.e. with a variable repetition rate, namely so often in time as necessary to deal with a control deviation which necessitates applying a PWM-adjustment by a fraction of the predetermined minimum pulse-width adjustment increment. Nevertheless, the case may also occur, where no pulse-width modulation adjustment at all is necessary, in these cases, namely for down to zero adjustments only, the single pulses, preferably of an extent according to the predetermined minimum pulse-width adjustment increment, are applied with the (modulatable) repetition rate set as necessary.

Thereby and in a further preferred mode, at the pulse frequency modulation, the accordingly modulated pulse repetition period is modulated by an integer multiple of the

pulse repetition period of the pulse-width modulation~~, according to claim 11~~.

For resolving the above mentioned object under the first aspect of the present invention there is further proposed a negative feedback control power supply ~~according to the wording of claim 15~~. Under its second aspect a negative feedback control power supply ~~according to the wording of claim 16~~ resolves the above mentioned object, and in a ~~far~~ preferred mode the objects under both of the aspects of the present invention are resolved by the digital negative feedback control power supply ~~according to claim 14~~, which combines both aspects of the present invention.

Preferred embodiments of the inventive negative feedback control power supply under both its aspects ~~are further defined in the claims 18 and 19 and~~ will additionally become apparent from the following detailed description. Further, the inventive power supply, especially combining both aspects, is applied to magnet-supply of a synchrotron, thereby resulting in an inventive synchrotron system ~~as of claim 20~~.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWINGS

In the detailed description, preferred embodiments of the present invention will be described as examples and referring to figures. These figures show:

Please replace the paragraphs beginning on page 9, line 9 and ending on page 9, line 16 with the following replacement paragraph:

FIG. 7 ~~in a representation according to FIG. 4, a today's most preferred embodiment~~ an embodiment in accordance with figure 4.

DETAILED DESCRIPTION OF THE INVENTION

In FIG. 1 there is shown, by means of a simplified functional block/signal-flow diagram a preferred embodiment of the negative feedback controlled power supply according to the present invention and operating according to a preferred variant of the inventive method, both under the first aspect of the present invention.

Please replace the paragraph beginning on page 10, line 13, with the following replacement paragraph:

According to the embodiment of FIG. 1 and thereby according to the present invention under its first aspect, the input E.sub.5 of the monitoring unit 5, with the analog monitoring signal X.sub.m, is operationally connected to the analog inputs E.sub.15a and E.sub.15b of at least two analog to digital converters (ADC) 15a and 15b of monitoring unit 5. The digital signal outputs A.sub.15a and A.sub.15b of the ADCs 15a, 15b are operationally connected to superimposing unit 17.

Please replace the paragraph beginning on page 11, line 18, with the following replacement paragraph:

Thus, the overall sampling rate is ~~risen~~ increased by the number k of parallely processed conversions, without the need of resolving at a single ADC the problems for ~~accordingly rising~~raising the oversampling rate.

Please replace the paragraph beginning on page 12, line 11 with the following replacement paragraph:

The adjusting unit 30 is construed as a power pulse-width modulation unit. A control signal applied to control input C.sub.30 controls pulse-width within the pulse repetition period T.sub.p of the pulse-width modulation PWM. Additionally, every pulse applied to C.sub.30 leads to transmission of power from E.sub.30 to A.sub.30 during the time extent of such pulse. Pulse-width modulation of power delivered to load 3 from power adjusting unit 30 may be said to be controlled by a control signal C.sub.PWM defining for a controlling pulse-width modulated signal, which is generated within controller unit 37 by

a pulse-width control unit 39. In block 39 the control signal C.sub.PWM is shown as a pulse-width modulated analog signal~~;~~ also it will be represented in a preferred mode by a digital control signal.

Please replace the paragraphs beginning on page 13, line 3 and ending on page 15, line 14 with the following replacement paragraphs:

Still according to the invention under this second aspect, the output signal of monitoring unit 35 is operationally connected via input E.sub.37 of controller unit 37 to a difference forming unit 41, as controlled signal X. At difference forming unit 41, from the controlled value X and a rated value W, generated by a rated value source 43, a control deviation signal .DELTA. is generated. The control deviation .DELTA. is fed via a controller (not shown~~-here~~) to a calculating unit 43.

FIG. 4 shows in more details, what operations are principally performed inventively at calculation unit 43. In a function of the actual control deviation signal .DELTA., calculation unit 43 determines, as schematically shown in FIG. 4, in block 45, a desired adjustment .delta..sub.des which would have to be applied to the control input C.sub.30 of power adjusting unit 30, to negative feedback control the power P.sub.a delivered to the electric load 3 exactly to match the desired value W so that .DELTA. becomes at least approximately zero. Nevertheless, and as was explained, power adjusting unit 30 and/or pulse-width modulation control unit 39 are limited with respect to the minimum predetermined adjustment increment .delta..sub.min with which pulse-width T.sub.mod may be changed. Therefore, the present invention under this aspect considers that although no pulse-width adjustment increments may be applied which are smaller than .delta..sub.min, frequency with which a pulse-width adjustment is applied is an additional parameter which allows controlling the effect on the power output at A.sub.30.

As will be explained, the drawback that pulse-width modulation provides for a predetermined minimum pulse-width adjustment increment .delta..sub.min is bypassed by introducing additionally to pulse-width modulation PWM, pulse frequency modulation PFM. ~~We understand by~~In pulse-frequency modulation PFM, ~~applying~~ pulses of

predetermined fixed length are applied and ~~varying~~ the repetition rate of these pulses are varied.

As schematically shown in FIG. 4 by block 47, calculating unit 43 determines as a possible form of realization the ratio R of the desired adjustment increment .delta..sub.min and the predetermined minimal adjustment increment. ~~Let's~~ by way of ~~assume~~ assumption this ratio results in a number R=2.6. Unless the desired adjustment .delta..sub.des accords exactly with an integer multiple of the predetermined minimum pulse-width adjustment increment .delta..sub.min, R may be written as R=I.multidot.10.sup.0+F.mu- ltidot.10.sup.-1 as of 2.6 with I=2.multidot.10.sup.0 and F=6.multidot.10.sup.-1. Thus, the result of ratio forming in unit 47 is split in an integer I and a fraction F. The integer number I directly controls ~~directly~~ adjustment of pulse-width T.sub.mod of the pulse-width modulation by the according number of increments I.multidot..delta..sub.m- in in each pulse repetition period T.sub.p. This accords to customary pulse-width modulation control~~;~~.

The fractional number F, in the above example of 0.6, is used to apply additionally to the pulse-width modulation a pulse train, which is pulse frequency modulated PFM and with a preferably fixed pulse, preferably of time extent .delta..sub.min. Thus, such additional pulse is ~~not anymore~~no longer applied in succeeding pulse repetition periods T.sub.p, but just as often as necessary to have, averaged over time, the same effect on the power at A.sub.30 as if in every pulse repetition period T.sub.p the pulse length would be changed by F.multidot..delta..sub.min, which is not feasible. If we take T.sub.p as a time unit, the time period with which an impulse of extent .delta..sub.min is to be applied becomes T.sub.PFM=1/F, thus for our example T.sub.PFM=1,67. Thus, instead of applying a respective adjustment of pulse-width in every time frame according to every pulse repetition period T.sub.p, the repetition period prevailing for applying a single additional pulse of extent .delta..sub.min is modulated to (1:F).multidot.T.sub.p.

Please replace the paragraphs beginning on page 16, line 3 and ending on page 16, line 14 with the following replacement paragraph:

Therefore, in a preferred embodiment, the frequency-modulated signals with pulses of the extent .delta..sub.min are applied during F.multidot.N of succeeding pulse repetition periods T.sub.p wherein N stands for a number of succeeding pulse-repetition periods of pulse-width modulation. According to the above mentioned example and taking N e.g. to be 10, ~~this means that~~ the single pulse of .delta..sub.min is applied to 6 pulse repetition periods T.sub.p out of 10.

~~Thereby, in fact~~ Accordingly, frequency modulation is performed in discrete steps of pulse repetition period T.sub.PFM which step being T.sub.p. This preferred realization form is shown in FIG. 4 by dashed lines.

Please replace the paragraph beginning on page 17, line 21, with the following replacement paragraph:

By this adjustment in that period T.sub.p considered, the prevailing value of the control deviation and of the ratio R again drops. By resetting unit 48 as schematically shown at R.sub.s in FIG. 7 as soon as its output signal reaches unity, in the subsequent periods T.sub.p pulse-width, is kept adjusted by I.multidot..delta..sub.min.

By realizing such combined technique with two 16 bit analog to digital converters 15 according to FIG. 1, each operated at a sampling rate of 100 kHz, and by realizing pulse-width modulation with superimposed pulse frequency modulation as was described especially with the help of FIG. 4 and 6, there was achieved an accuracy of resolution of at least 10 ppm and even down to a resolution accuracy of 1 ppm. This for a power supply for at least 100 VA power used for power supplying the magnet arrangement of synchrotron magnets.